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(54) **DIELECTRIC BARRIER DISCHARGE LAMP WITH TUBE REMNANT DISCHARGE CHAMBER CONNECTION**

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(30) **Foreign Application Priority Data**

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(52) **U.S. Cl.** **313/234**; 313/493; 313/634; 313/635; 313/607
(58) **Field of Search** 313/493, 634, 313/635, 607, 234; 315/248

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(57) **ABSTRACT**

To enable the easy and adequately reliable cleaning of the inner surface of the chamber material, and as a result, to provide a dielectric barrier discharge lamp with good lighting characteristics and simplicity of manufacture, a dielectric barrier discharge lamp having a discharge chamber with a cylindrical, double-tube construction with an outer tube and an inner tube, in which the cylindrical discharge space formed between the outer tube and the inner tube is filled with a discharge gas in which excimer molecules are formed by a dielectric barrier discharge, two or more fluid distribution tube remnants connecting to each discharge chamber. It is preferable that the dielectric barrier discharge lamp described above have two or more fluid distribution tube remnants formed on opposite ends of the discharge chamber.

2 Claims, 4 Drawing Sheets

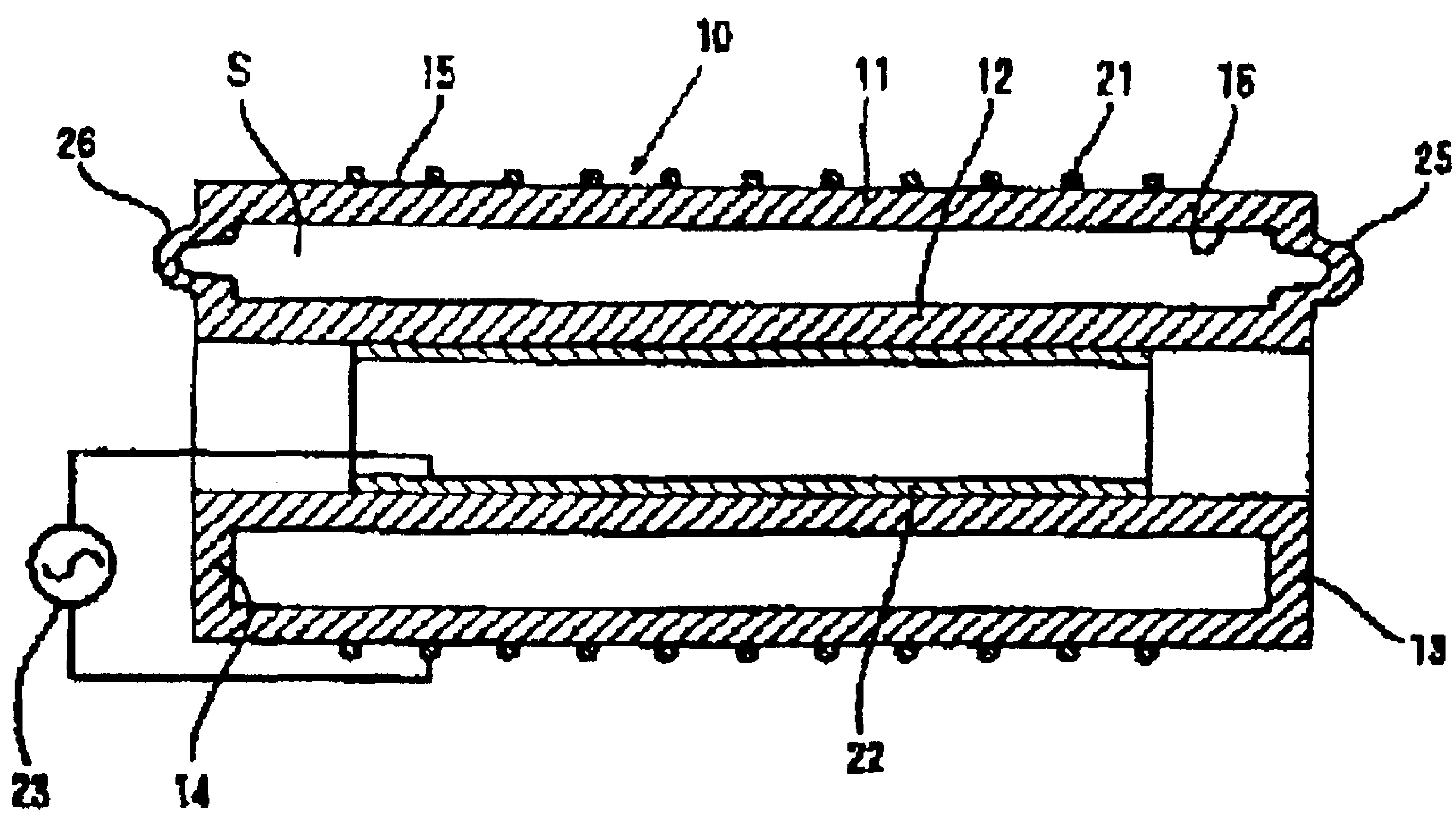


FIG. 1

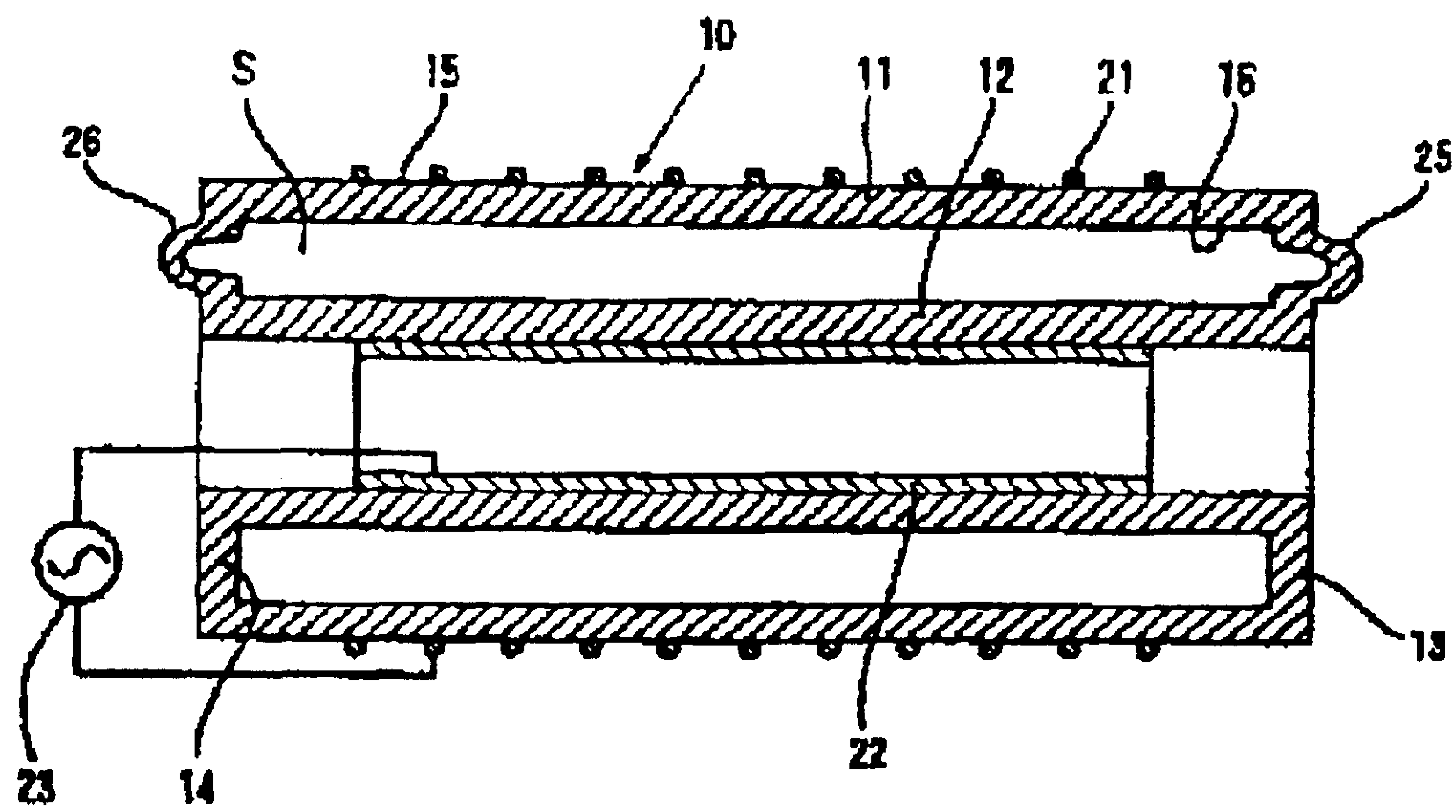


FIG. 2

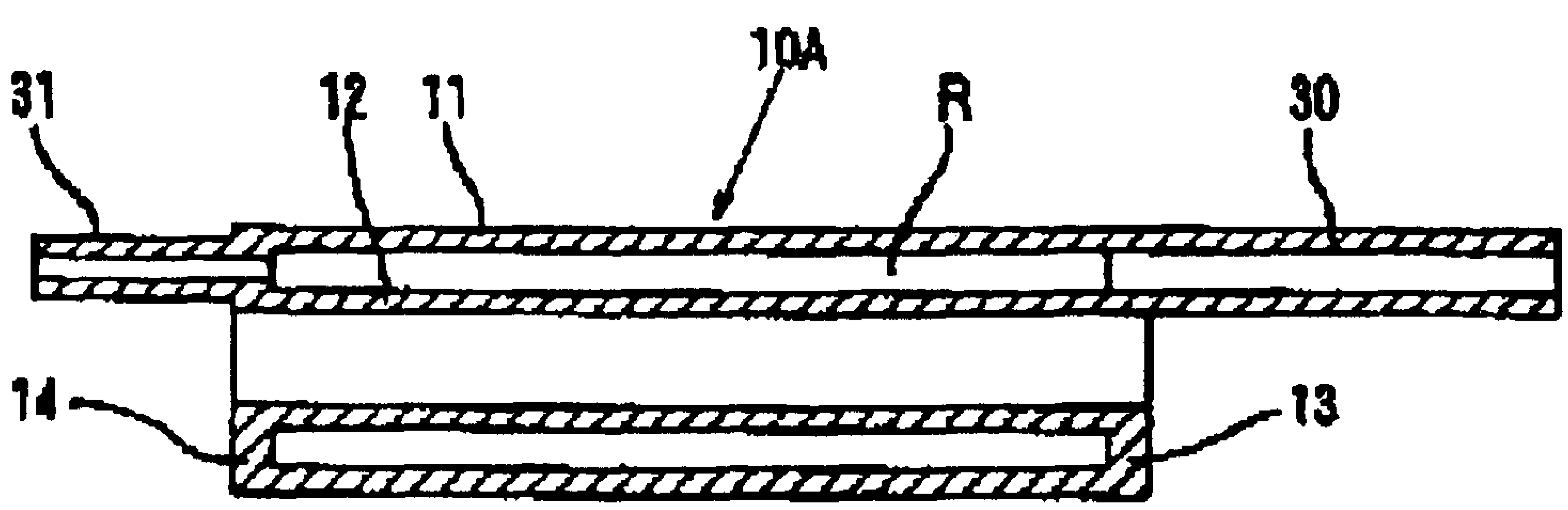


FIG. 3

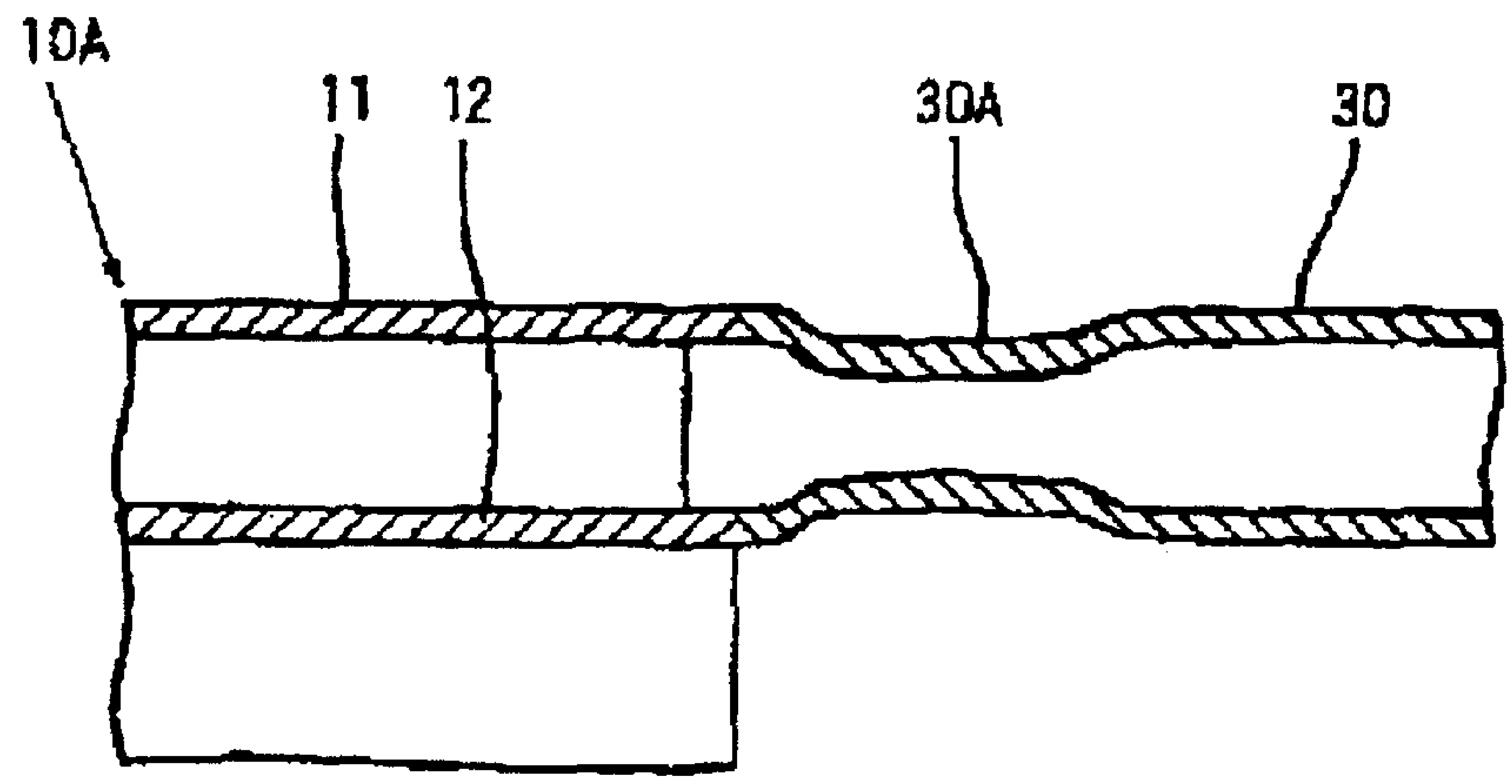


FIG. 4

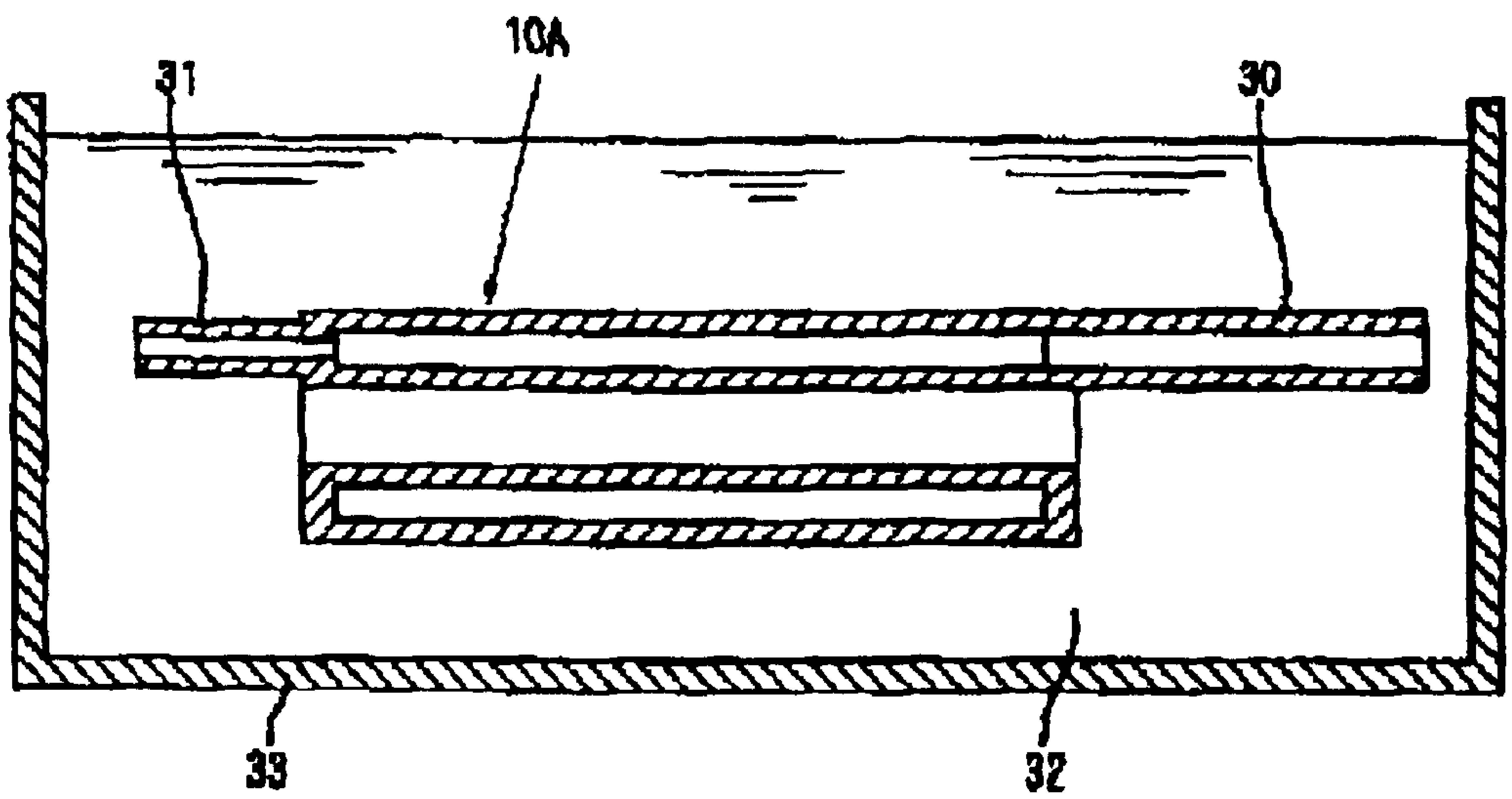


FIG. 5

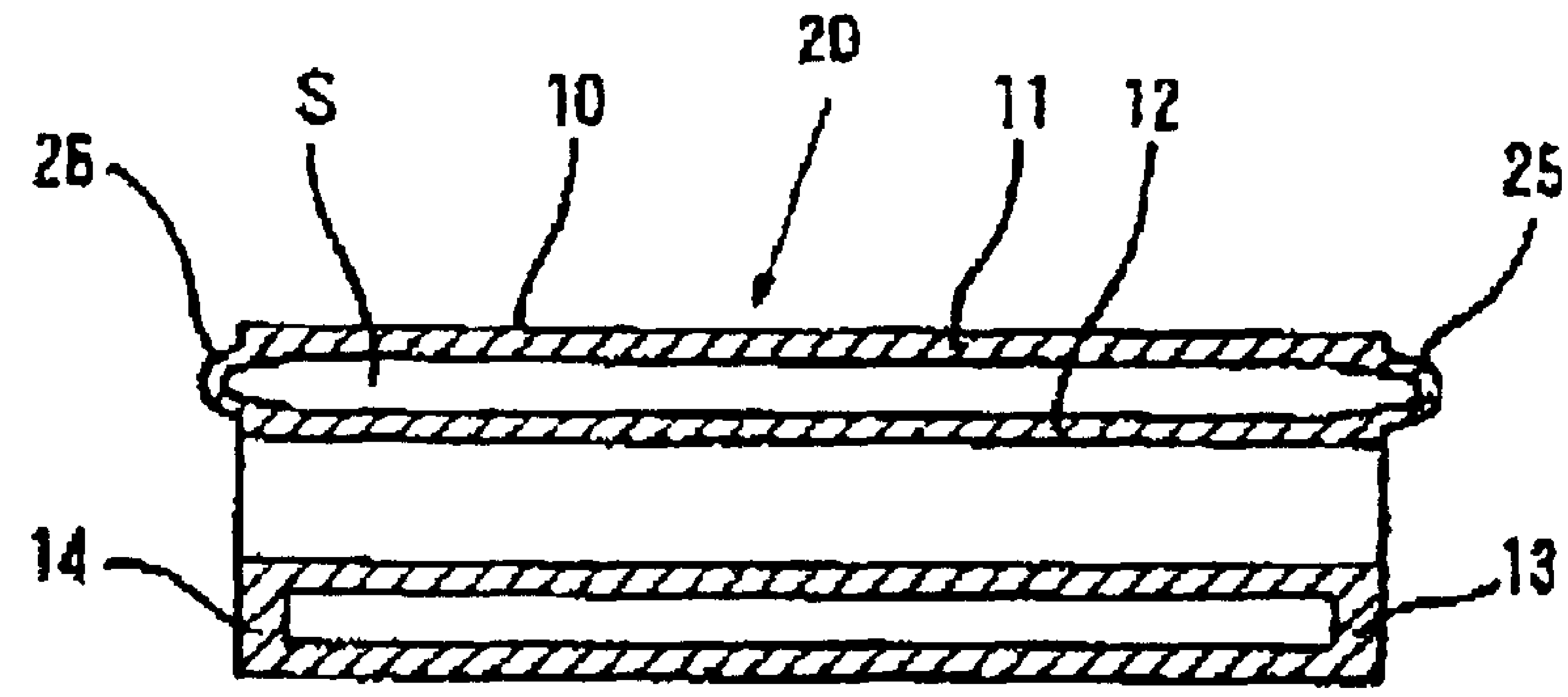


FIG. 6

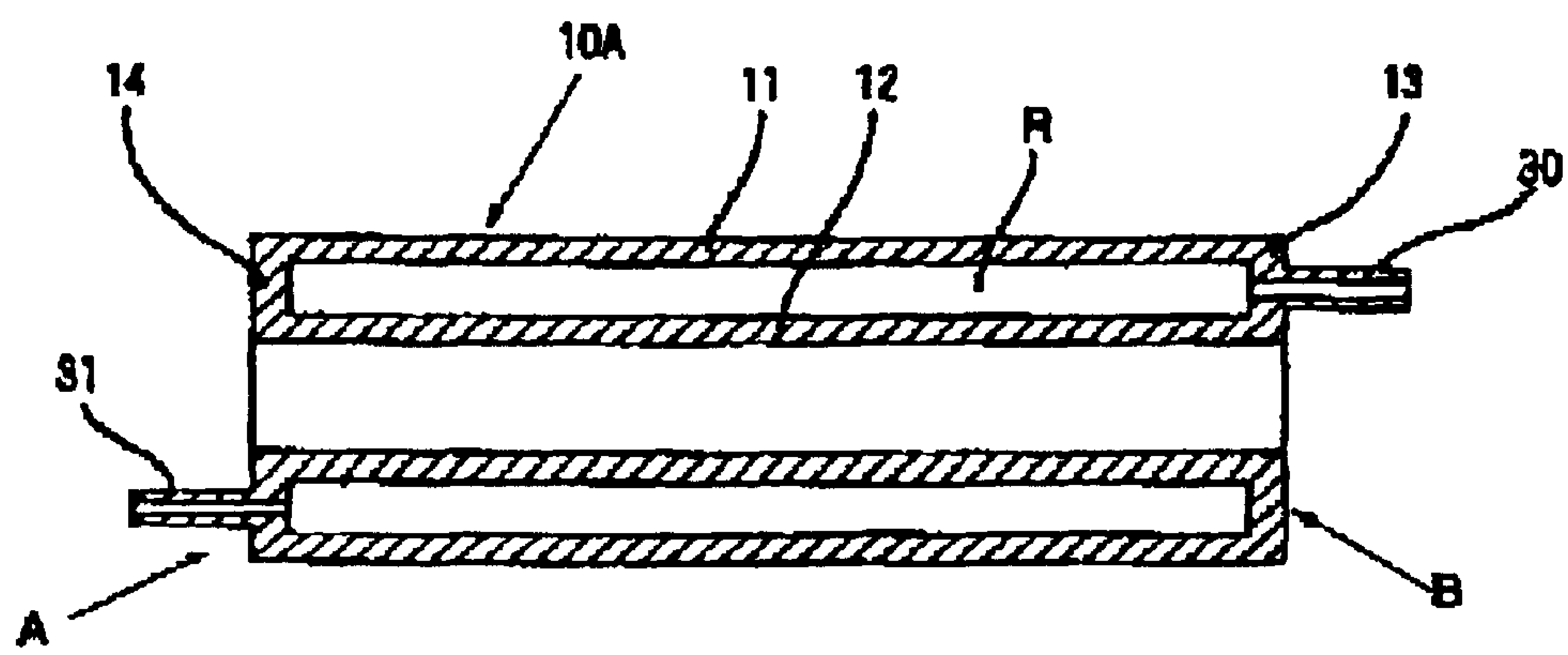


FIG. 7
(Prior Art)

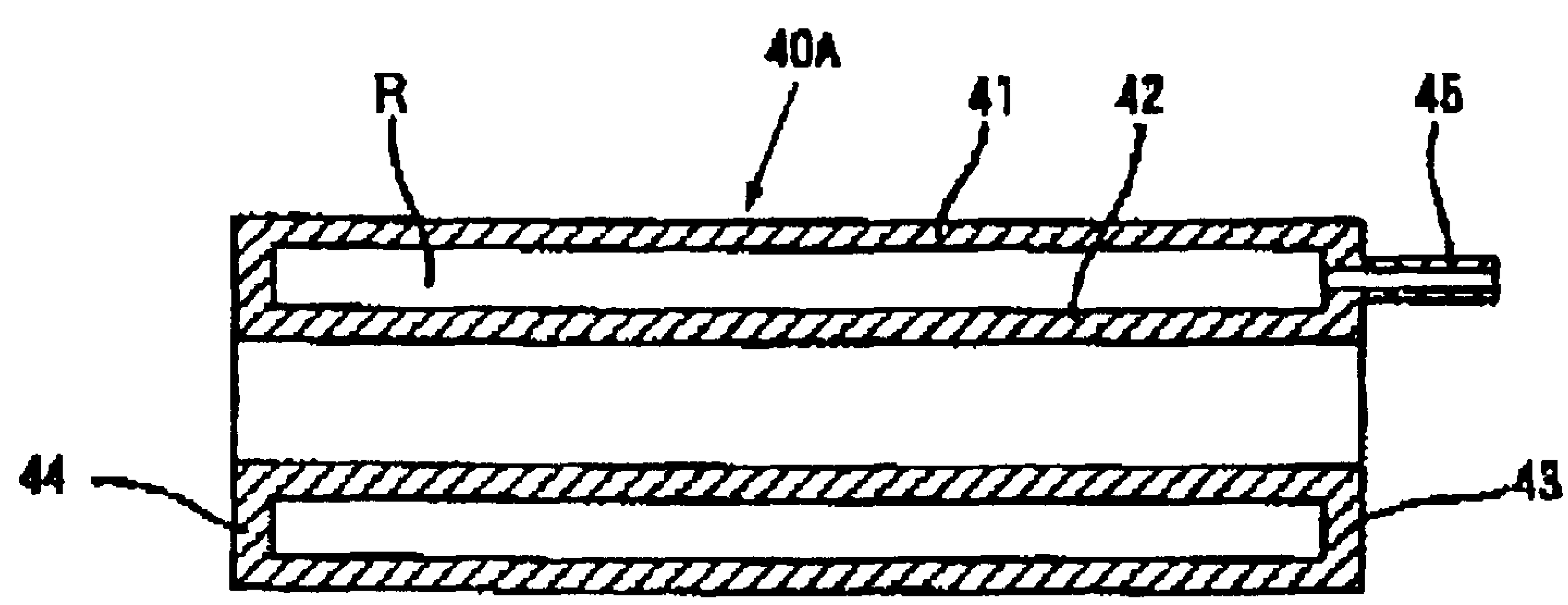


FIG. 8
(Prior Art)

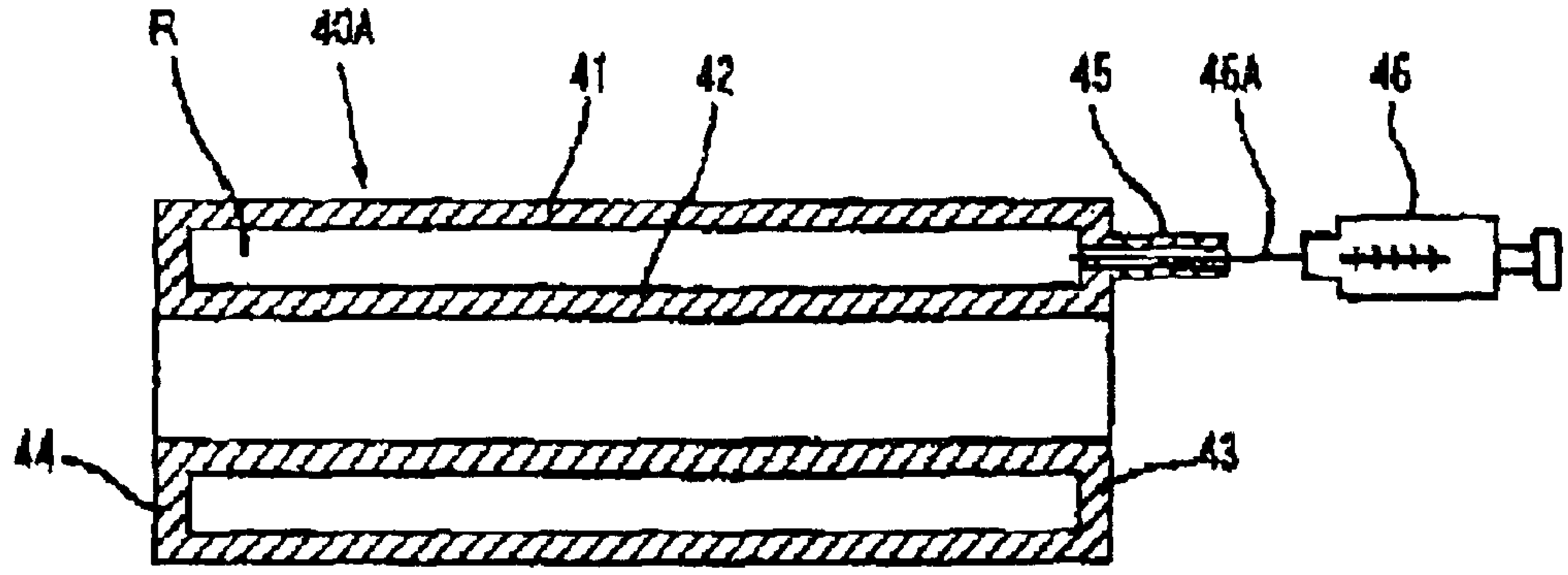
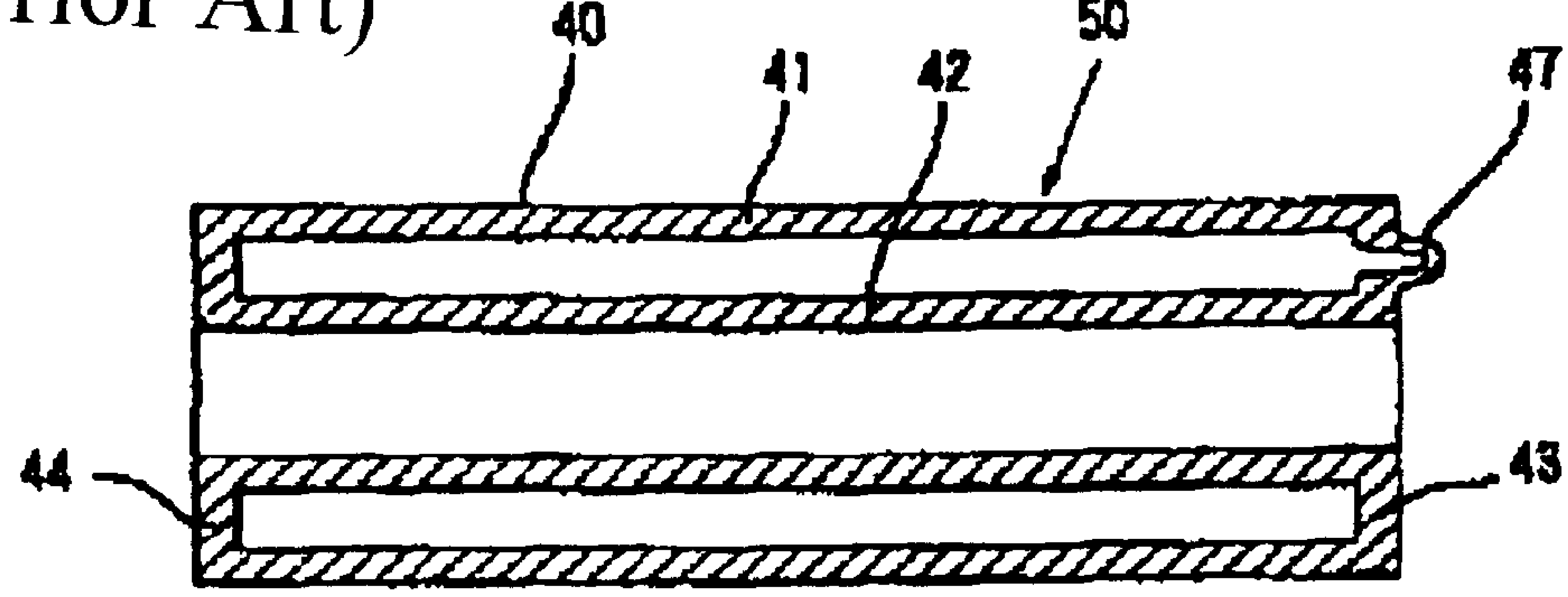


FIG. 9
(Prior Art)



DIELECTRIC BARRIER DISCHARGE LAMP WITH TUBE REMNANT DISCHARGE CHAMBER CONNECTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns dielectric barrier discharge lamps that use dielectric barrier discharges to emit excimer light.

2. Description of Related Art

Recent years have seen the development and practical application of surface treatment technology in which metals, glass and other materials are irradiated with vacuum ultraviolet light at wavelengths of 200 nm or less, in which the action of the vacuum ultraviolet light irradiation heat treatment equipment and the ozone produced thereby affect the material being treated, including cleaning treatment technology that removes organic pollutants adhered to the surface of the material being treated, and oxide film formation technology that forms an oxide film on the surface of the material being treated.

The lamps used to conduct this sort of ultraviolet treatment have been dielectric barrier discharge lamps that have a discharge chamber made of a dielectric and filled with an appropriate gas for excimer light, in which a dielectric barrier discharge (also called an "ozonizer discharge" or "silent discharge"—see Denki Gakkai: "Discharge Handbook,"rev. ed. June 1989, p 263) in the discharge chamber produces excimers and causes the emission of excimer light.

An example of a method of producing such a dielectric barrier discharge lamp is described below. FIG. **7** is an explanatory cross-section showing an example of the structure of the chamber material to form the discharge chamber in a conventional dielectric barrier discharge lamp. In this figure, **40**A is chamber material to form the discharge chamber of the dielectric barrier discharge lamp. It has a two-layer structure comprising a cylindrical outer tube **41** and an inner tube **42** made of quartz glass, which is a dielectric. The two ends of the outer tube **41** and the inner tube **42** are joined by end walls **43**, **44**, and the space between the outer tube **41** and the inner tube **42** forms a toroidal internal space R. Additionally, an exhaust tube **45** is attached to the end wall **43** so as to connect to the internal space R.

Before the internal space R is filled with a discharge gas, the interior of this chamber material **40**A is cleaned, perhaps by inserting a needle **46**A of a syringe **46** into the exhaust tube **45**, as shown in FIG. **8**, and injecting a cleaning reagent, such as an aqueous solution of ammonium fluoride, for example, into the chamber material **40**A. Then, after the interior surface of the chamber material **40**A has been cleaned, the cleaning reagent is shaken out of the chamber material **40**A. After that, the chamber material **40**A is rinsed with water to wash out any remaining cleaning reagent; the rinse water is injected and removed in the same way as the cleaning reagent was.

After the chamber material **40**A with its clean inner surface is dried, the exhaust tube **45** is connected to exhaust equipment, the air in the internal space R is exhausted, and the internal space R is filled with the discharge gas. Then, as shown in FIG. **9**, the exhaust tube **45** is burned off and the internal space R is sealed by means of a burner, for example, producing a lamp proper **50** that has discharge gas sealed into the discharge chamber **40** with an exhaust tube remnant **47**.

The dielectric barrier discharge lamp is produced by using appropriate means to attach an electrode to the outer surface of the outer tube **41** of the lamp proper **50**, and another electrode to the inner surface of the inner tube **42**.

Nevertheless, there are the following problems when dielectric barrier discharge lamps are manufactured by the method described above. It is difficult to perform, with high work efficiency, the operations of injecting and removing the cleaning fluids into and out of the chamber material **40A** through the exhaust tube **45** attached to the chamber material **40A**. As a result, the manufacture of dielectric barrier discharge lamps requires a long time.

Moreover, because it is difficult to perform the operations of injecting and removing the cleaning fluids into and out off the chamber material **40A**, there are times when the inner surface of the chamber material **40A** cannot be cleaned adequately, and dirt or foreign objects remain inside the chamber material **40A**. As a result, when a dielectric barrier discharge lamp is manufactured using that chamber material **40A**, good discharges in that dielectric barrier discharge lamp will be obstructed, the lighting intensity will drop, and a lighting flaw will occur.

SUMMARY OF THE INVENTION

This invention is based on the situation described above, and has a primary object of providing a dielectric barrier discharge lamp of which the inner surface of the chamber material can be cleaned easily and reliably, which consequently has good lighting characteristics, and which is easy to manufacture.

This object is achieved by the invention by a dielectric barrier discharge lamp having a discharger chamber with a cylindrical, double-tube construction comprising an outer tube and an inner tube, in which the cylindrical discharge space formed between the outer tube and the inner tube is filled with a discharge gas in which excimer molecules are formed by a dielectric barrier discharge, and in the discharge chamber is formed with at least two fluid distribution tube remnants that connect to each discharge chamber.

It is preferable that the dielectric barrier discharge lamp described above have two or more fluid distribution tube remnants formed on opposite ends of the discharge chamber.

In the manufacture of the dielectric barrier discharge lamp constituted as described above, there are two or more fluid distribution tubes on the chamber material that makes up the discharge chamber, and so it will be possible, while using at least one fluid distribution tube as a route for injection or removal of cleaning fluids, to secure the other fluid distribution tube as a route for air in the chamber material to be discharged, and so the action of injecting cleaning fluids into the chamber material and the action of removing them can be performed easily and reliably. As a result, it is possible to clean and remove dirt and foreign objects from the inner surface of the chamber material. Thus, it is possible to prevent drops in lighting intensity and the occurrence of lighting flaws that originate from dirt or foreign objects on the inner surface of the chamber material, and so it is possible to obtain good lighting characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is sectional view of one example of the dielectric barrier discharge lamp of this invention.

FIG. **2** is a sectional view showing one example of the structure of the chamber material to form the discharge chamber in the dielectric barrier discharge lamp shown in FIG. **1**.

FIG. **3** is a sectional view showing the detail of a connection between the first fluid distribution tube and an end wall of the chamber material shown in FIG. **2**.

FIG. **4** is an explanatory drawing showing an example of the method of injecting cleaning agent into the chamber material shown in FIG. **3**.

FIG. **5** is a sectional view showing the lamp proper resulting from the sealing process.

FIG. **6** is a sectional view of the chamber material showing an example of connection of the fluid distribution tubes.

FIG. **7** is a sectional view showing an example of the structure of the chamber material to form the discharge chamber in a conventional dielectric barrier discharge lamp.

FIG. **8** is a sectional view showing an example of the method of injecting cleaning agent into the chamber material shown in FIG. **7**.

FIG. **9** is a sectional view showing the lamp proper resulting from the known sealing process.

DETAILED DESCRIPTION OF THE INVENTION

The mode of implementation of the dielectric barrier discharge lamp of this invention is explained below. FIG. **1** shows the structure of one example of a dielectric barrier discharge lamp in accordance with this invention. This dielectric barrier discharge lamp has a sealed discharge chamber **10** with a two-layer structure comprising a cylindrical outer tube **1** made of dielectric, and a cylindrical inner tube **12** made of dielectric that is concentric with the outer tube **11** and has an outside diameter smaller than the inside diameter of the outer tube **11**. In this discharge chamber **10**, the ends of the outer tube **11** and the inner tube **12** are connected by end walls **13**, **14**, thus forming a toroidal discharge space S, between the outer tube **11** and the inner tube **12**, which is filled with a discharge gas.

The dielectric material that makes up the discharge chamber **10** can be one that is transparent to the excimer light emitted from the discharge chamber **10**, such as synthetic quartz glass. The discharge gas sealed in the discharge chamber **10** can be one that emits excimer light with a wavelength of 200 nm or less, such as xenon gas or a mixture of argon and chlorine.

There is one electrode **21**, perhaps a mesh of metal or other electroconductive material, in close contact with the outer surface **15** of the outer tube **11** of the discharge chamber **10**, as well as another electrode **22**, perhaps a sheet of aluminum, in close contact with the inner surface **16** of the inner tube **12**. This other electrode **22** can be made up of two semi-cylindrical aluminum sheets, pressed by a suitable pressure piece against the inner surface **16**. The electrode **21** and the electrode **22** are connected to a high frequency power supply **23**. Two fluid distribution tube remnants **25**, **26** are formed on the end walls **13**, **14** at the ends of the discharge chamber **10**, and so that the fluid distribution tube remnants **25**, **26** are separated in the axial direction.

The dielectric barrier discharge lamp described above is manufactured as follows. FIG. **2** shows the chamber material **10A** used in the manufacture of the dielectric barrier discharge lamp of FIG. **1**. This chamber material **10A** has the same basic structure as the chamber material **40A** shown in FIG. **7**; there is a first fluid distribution tube **30** on one end wall **13**, and a second fluid distribution tube **31** on the opposite end wall **14**, both of which are connected through to the internal space R. The first fluid distribution tube **30** and the second fluid distribution tube **31** have different tube diameters, the diameter of the first fluid distribution tube **30** being greater than that of the second fluid distribution tube **31**.

FIG. **3** is an explanatory cross-section showing an expanded portion of the connection between the first fluid distribution tube **30** and the end wall **13** of the chamber material **10A** shown in FIG. **2**. A reduced-diameter portion **30A** of the first fluid distribution tube **30** is formed close to the point of its juncture with one end wall **13**. This reduced-diameter portion **30A** is formed by heating with a burner, for example, and in a fluid distribution tube with an outer diameter of 8.0 mm and an inner diameter of 6.0 mm, the reduced-diameter portion **30A** would have an outer diameter of 5.0 mm and an inner diameter of 3.0 mm. A similar reduced-diameter portion (not illustrated) is formed in the second fluid distribution tube **31**.

Such a chamber material **10A** first undergoes the cleaning process. In the cleaning process a cleaning fluid of suitable concentration, such as 9 wt-% ammonium fluoride, is used for the reagent cleaning treatment, and cleaning water is used for the rinse treatment. In the reagent cleaning treatment, the chamber material **10A** is gradually placed into a reagent bath **33** filled with a reagent **32**, with the chamber material **10A** held at an angle with the first fluid distribution tube **30** downward. Then, as the clean reagent flows into the chamber material **10A** through the first fluid distribution tube **30**, the air inside the chamber material **10A** escapes through the second fluid distribution tube **31**, and so the cleaning reagent **32** fills the chamber material **10A** quite easily. The chamber material **10A** is left to soak in the reagent, as shown in FIG. **4**, for perhaps 30 minutes, after which it is removed from the reagent bath **33**. By removing the chamber material **10A** at an angle with the first fluid distribution tube **30** directed downward, the cleaning reagent **32** runs out through the first fluid distribution tube **30**, and at the same time, air flows into the chamber material **10A** through the second fluid distribution tube **31**. Thus, the cleaning reagent **32** is removed from the discharge chamber **10** quite easily.

Afterwards the chamber material **10A** is submerged in a bath filled with cleaning water by the same procedure used during the reagent cleaning treatment. After the inside of the chamber material **10A** has been rinsed, the chamber material **10A** is removed from the cleaning bath to complete the rinse treatment. This rinse treatment with cleaning water is preferable repeated, perhaps three times.

Following completion of the cleaning process, the chamber material **10A** is put through a drying treatment. In the drying treatment, the chamber material **10A** is placed with the first fluid distribution tube **30** upward in an electric furnace with its temperature set at 80° C., for example, and dried for about 1 hour.

Next, the chamber material **10A** goes through the sealing process. In this sealing process, the reduced diameter portion of the smaller-diameter second fluid distribution tube **31** is heated with a burner. By this means, the reduced diameter portion is burned through, and a dome-shaped fluid distribution tube remnant **26** is produced. Then, after the second fluid distribution tube **31** is sealed, an exhaust device is connected to the first fluid distribution tube **30**, by which means the air is exhausted from the internal space R, after which the internal space R is filled with a discharge gas such as xenon. After that, the reduced diameter portion of the first fluid distribution tube **30** is burned through with a burner, and a dome-shaped fluid distribution tube remnant **25** is formed. As a result, the internal space R is sealed, and a lamp proper **20** having a discharge chamber **10** sealed full of discharge gas is formed with two fluid distribution tube remnants **25, 26** formed on one end and on the other end, as shown in FIG. **5**.

Then, an electrode **21** is applied to the outer surface of the outer tube **11** of the lamp proper **20**, and another electrode **22** is applied to the inner surface of the inner tube **12**, thus producing a dielectric barrier discharge lamp with the constitution shown in FIG. **1**.

The following is an example of the measurements of the chamber material of the dielectric barrier discharge lamp of this invention described above. The outer tube **(11)** of the chamber material **(10A)** is 300 mm long, 26.5 mm outside diameter, 24.5 mm inside diameter, 2.0 mm wall thickness. The inner tube **(12)** is 300 mm long, 16 mm outside diameter, 14 mm inside diameter, 2.0 mm wall thickness. The capacity of the internal space (R) is 80 cm^3. The first fluid distribution tube **(30)** is 150 mm long, 8.0 mm outside diameter, 6.0 mm inside diameter, 2.0 mm wall thickness. The second fluid distribution tube **(31)** is 100 mm long, 6.0 mm outside diameter, 4.0 mm inside diameter, 2.0 mm wall thickness.

The dielectric barrier discharge lamp above is made with two fluid distribution tube remnants **25, 26** formed one on each end of the discharge chamber **10**, and accordingly, the two fluid distribution tube remnants **25, 26** are separated from each other along the tube axis of the discharge chamber **10**. Consequently, in the manufacture of the discharge chamber **10**, by using a chamber material **10A** with two fluid distribution tubes **30, 31** in positions separated from each other along the tube axis, it is possible to use at least one fluid distribution tube as a route for ingress and egress of cleaning fluid, and also to assure that the other fluid distribution tube is available as a route for the flow of air within the chamber material. Thus, the operations of filling the chamber material with cleaning fluid and emptying it again can be carried out quite smoothly and with adequately high efficiency.

Moreover, in the drying operation for the chamber material **10A**, the water vapor flows out the first fluid distribution tube **30** which is positioned upward, and so air circulates smoothly in the chamber material **10A**, and the chamber material **10A** can be dried efficiently as a result. Because of that the manufacture of the dielectric barrier discharge lamp of this invention is easier and the manufacturing time required can be shortened considerably.

Moreover the process of injecting cleaning fluid into the chamber material and the removal process can be carried out reliably, and so it is possible to reliably wash and remove dirt and foreign bodies from the inside surface of the chamber material **10A**. As a result, it is possible to prevent the occurrence of reduced light intensity or lighting flaws caused by dirt or foreign bodies inside the chamber material **10A**, and so it is possible to obtain good lighting characteristics.

The mode of implementation of this invention has been explained above, but the dielectric barrier discharge lamp of this invention is not limited to the mode of implementation described above; it is possible to make a variety of changes. For example, there is no particular limit on the number of fluid distribution tubes attached to the chamber material, nor to their diameter or location.

Specifically, it is preferable that the fluid distribution tubes be attached in positions that are somewhat separated from each other. If, when the first fluid distribution tube **30** is attached to the upper part of the end wall **13**, as shown in FIG. **6**, it is best if the position of the second fluid distribution tube **31** is at position A, separated from the second fluid distribution tube **31** in the axial direction of the chamber material **10A**, and separated from the first fluid distribution tube **30** in the radial direction. Alternatively, it can be in position B, on the same end wall **13** but radially separated with the inner tube **12** sandwiched between the two fluid distribution tubes. It is also possible to attach the fluid distribution tubes to the outer tube **11** or the inner tube **12** rather than to the end walls **13, 14** of the chamber material **10A**.

In the explanation above, the number of fluid distribution tubes attached to the chamber material is two, but the following explanation will deal with the case of chamber material with three fluid distribution tubes or four fluid distribution tubes attached. In the event that three fluid distribution tubes are attached to the chamber material, then for example, the first fluid distribution tube **30** would be attached to one end wall, the second fluid distribution tube would be attached to the other end wall, and the third fluid distribution tube would be attached to the outer tube. In that case, it is preferable that the third fluid distribution tube be attached in a position near to an end wall.

In the event that four fluid distribution tubes are attached to the chamber material, then for example, the first fluid distribution tube **30** would be attached to one end wall, the second fluid distribution tube would be attached to the other end wall, the third fluid distribution tube would be attached to the outer tube, and the fourth fluid distribution tube would be attached to the inner tube. In that case, it is preferable that the third fluid distribution tube and the fourth fluid distribution tube be attached in positions near to end walls.

With the constitutions described above, the operations of moving the cleaning fluids into and out of the chamber material will be highly efficient.

As a means of moving the cleaning fluid into the chamber material, it is possible to connect a connecting tube to any of the fluid distribution tubes, and inject the cleaning fluid through that connecting tube. The effect described above will be achieved in that event, since when the cleaning fluid is injected into the chamber material through the first fluid distribution tube, the air within the chamber material will escape through the second fluid distribution tube.

EFFECT OF INVENTION

In the manufacture of the dielectric barrier discharge lamp of this invention, two or more fluid distribution tubes are attached to the chamber material that makes up the discharge chamber, and so when one or more of the fluid distribution tubes are being used to move cleaning fluids into or out of the chamber material, the other fluid distribution tube or tubes can be kept as a route for air to move out of or into the chamber material. Therefore, the operation of moving cleaning fluids into or out of the chamber material can be performed easily and reliably. Consequently, it is possible to reliably clean and remove dirt and foreign objects from within the chamber material, and it is thus possible to prevent reduced lighting intensity or lighting flaws caused by dirt or foreign objects on the inner surface of the chamber material, so that it is possible to attain good lighting characteristics.

What is claimed is:

1. A dielectric barrier discharge lamp having a discharge chamber with a cylindrical, double-tube construction comprising an outer tube and an inner tube, in which a cylindrical discharge space formed between the outer tube and the inner tube is filled with a discharge gas in which excimer molecules are formed by a dielectric barrier discharge; wherein the discharge chamber is formed with remnants of two or more fluid distribution tubes that connect to the discharge space of the discharge chamber.

2. A dielectric barrier discharge lamp as described in claim **1**, wherein the two or more fluid distribution tube remnants are formed on opposite ends of the discharge chamber.

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